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ENGINEERING PROGRESS IN THE UNITED STATES.

NOTE.—The President being unable to deliver the Annual Address in consequence of his journey to Europe, it has, at his request, been prepared by Mr. O. CHANUTE, Vice-President, with the assistance of members of the Society.

It has sometimes been said that, when in after centuries historians write of the period in which we now live, they will probably characterize

it as the age of material and mechanical development; as the time when man fairly entered upon the mastery of the earth upon which he lives.

We are in, and part of the movement, and perhaps we cannot well be judges over ourselves, but we can realize at least that, while various periods have been marked by human activity in other directions, from the end of the eighteenth century dates the time when man began to utilize, on a large scale, the powers of nature, and to make our world a more comfortable abiding place for its inhabitants. That since the steam engine came to increase, more than tenfold, the productive forces of men, we have entered upon a period of enormous producing and cheapening of all the necessities, and of many of what used to be considered the superfluities of life.

Brought forward by the requirements of this utilitarian movement, the engineer has become one of its most important agents. To him, as a trained constructor and scientific mechanic, is entrusted the task of executing the works by means of which the cost of production and of distribution are cheapened. His business is to design and to superintend required improvements, to invent or to bring into practical use labor and time-saving appliances, and his art was well defined by Telford, in the constitution of the British Institution of Civil Engineers as, "the art of directing the great sources of power in nature, for the use "and convenience of man."

We seldom realize how very young is our profession. From the earliest historical periods, until within about two hundred years, construction, practically, was in the hands of architects. They built pyramids, temples, roads, fortifications, and such weak machines as they could work by hand, but it is only in modern times that a special body of men has devoted itself exclusively to the building of works and machines for utilitarian purposes; to the emancipation from toil of the "hewer of wood and the drawer of water."

So recently as two hundred years ago, when the English people began the works which have made them one of the great nations of the earth, there was such a lack of trained constructors in their country, that they were compelled to send to Holland for what were then called "Hydraulic Architects," to direct the reclaiming of their marshes and to inaugurate their canals. Soon, however, they excelled their early teachers, and trained the very able engineers who established the

modern profession, and whose labors led to the invention of the steam engine scarcely a century ago.

We, who cannot remember the time when steam engines were not in common use, can scarcely realize that their introduction was so recent; and yet, it was only in 1778, that James Watt, after struggling for over twenty years to remedy the imperfections of such machines (as invented by others,) finally triumphed over all the mechanical difficulties he encountered, and began the regular manufacture of steam engines.

By this step, an enormous impetus was given to development and invention. Not only did the engineer find himself possessed of an instrument which increased many fold the productive powers of labor, but the use of steam, and the wonders it accomplished, turned men's thoughts to the advantages of machinery and labor saving appliances. Invention followed invention in every field of mechanics, fresh discoveries of natural laws took place, which were quickly applied by the engineer, and he has been able to accomplish more in the past 100 years than had been achieved in the previous ten centuries.

It is my purpose to-night cursorily to pass in review what has been done in this direction in this country. In doing this, I shall touch upon some fields which are as yet scarcely recognized here as within the province of the engineer, but which are falling into his hands in other countries, and probably will in this. I think you will agree with me, that starting as an independent nation about a century ago, with a population of some 3,000,000 thinly scattered, and with next to no capital, the modern inventions which we have appropriated or made, have enabled us to accomplish very remarkable results.

Water Works.

The first works in America for the supply of water to towns, were constructed by Hans Christopher Christiansen, and put in operation on June 20th, 1754, at the Moravian settlement of Bethlehem, in Pennsylvania.

The water from a spring, which is still used for the supply, was forced by a pump of lignum-vitæ of five inches bore, through hemlock logs into a wooden reservoir.

The same ingenious Dane, eight years later, replaced this rude pump by three iron pumps of four inches bore and eighteen inches stroke, which for many years were the only machinery for water supply on the Continent, and for seventy years furnished the water for Bethlehem.

Among the oldest, if not the very next in date to Bethlehem, is the Morristown, N. J., Water Company, which was incorporated in 1791, and has ever since furnished the town with water collected from the neighboring hills.

The first application of steam to pumping was in Philadelphia, in 1800, when the third steam engine of any considerable size in the United States was erected on the banks of the Schuylkill. It is believed that these works were the first constructed by a municipality. The first cast iron water pipes were laid in Philadelphia in 1804.

New York was first supplied by a company which erected a small pumping engine about 1800.

During the first thirty years of the century several small works were constructed, among others, at Cincinnati, in 1817; at Detroit, in 1827; at Lynchburgh, in 1828; Syracuse, in 1829; and Richmond, in 1830. Few of these works exhibited any great advance in engineering. The enlarged works for the supply of Philadelphia by water power, constructed at Fairmount, in 1822, showed however a marked advance, and were for many years regarded as a model of efficient and economical works. The design and execution of the gravity supply works for New York and for Boston, between 1830 and 1840, were such as can not be greatly improved, even at the present day, except in some minor details.

About 1850 the substitution of light wrought iron pipe, lined inside and out with hydraulic cement, for cast iron, at greatly reduced cost, was found to be practicable in many cases, and the formation of companies to manufacture and lay such pipes, introduced a commercial element into the matter of water supply, and led to the construction of many works.

Improved forms of pumping machinery, which performed a fair duty at small expense for construction and maintenance, were designed and their manufacture became a special business.

The careful analysis and investigation employed in the construction of the works for the supply of Brooklyn, between 1850 and 1860, resulted in a more decided advance, in both theoretical and practical science, than had hitherto been made, the effects of which were seen during the succeeding decade in improvements in pipe manufacture, in engine building, in reservoir construction and in maintenance of works.

Between 1860 and 1870, a further impetus to water works construction, was given by the vigorous prosecution of an enterprise for building entire works for direct supply, by pumping into the mains without the intervention of a reservoir. The success attending this enterprise, owing to the small first cost of construction and to shrewd management, created competition, the result of which has been to force the adoption of scientific methods and the employment of skilled engineers, and as a consequence there has been great improvement in the types of machinery and in economical working.

The pumping machinery of large cities has also been greatly improved; the duty now required, and uniformly maintained, being at least fifty per cent. greater than it was thought possible to obtain twenty years ago, or than is now furnished by the less costly "commercial engines," of which two firms alone have built 242 for 168 towns, with an aggregate pumping capacity of 734 millions of gallons per day.

The construction by Mr. Chesbrough of a submarine tunnel for two miles under Lake Michigan, to furnish water for Chicago, was one of the boldest engineering feats of this century. Its successful completion was followed by the construction of several similar works.

On the Pacific coast, the use of unprotected wrought iron pipe for conveying water great distances, and under great pressure, has proved very successful.

During the past ten years, the most important work executed, has been the enlargement of the gravity supply for Boston, by the construction of a conduit of masonry, in the designing and erection of which the latest and most perfect methods have been followed. The subjects to which particular attention has been paid by engineers during this period have been the efficiency of pumping machinery, the capacity of gathering grounds, the preservation of the purity of the water, and the prevention of waste by consumers.

All American works are constructed for a constant supply, and most of those first built had a capacity far in excess of the then demand, which caused the formation of habits of wastefulness, which it has been found difficult to check when the limit of the capacity was nearly reached.

The magnitude of the interests involved in this branch of engineering, may be judged from the fact that there are now in the United States and Canada, 569 towns with a public water supply, having a population of

about twelve millions, to whom there are daily distributed over six hundred millions of gallons of water, through thirteen thousand miles of pipes, of which about ten thousand miles are of cast iron.

About one half of these towns are supplied by gravity, many of them, however, having supplemental pumping power. The total capacity of the pumping engines now in use being about 1 900 millions of gallons per day.

Meanwhile improvements in plumbing and house distribution have greatly added to the convenience about our homes, and we now virtually have a spring of cold, and another of hot water, in almost every room of our city houses, to put on tap at will.

Hydraulics.

The attention of manufacturers was drawn at an early day, to the development of the water power of the streams on the Atlantic coast. With the aid of capitalists who appreciated the value of an investment in experimental researches, some of the most effective efforts, towards the solution of problems in practical hydraulics, have been made by American engineers, on a scale unattempted in Europe.

The early foreign experiments, on which most of the formulæ for the discharge of water from weirs, orifices and pipes are based, were on too small a scale, to furnish data capable of generalization, for greater discharges.

The experiments of Mr. Jas. B. Francis, at Lowell, have among other valuable results, established correct values for the co-efficient of discharge of weirs, and his formula is now generally used.

The researches which have been made at Holyoke and Lawrence, have done much to settle disputed points in relation to the movement and effect of water in channels, and the systematic experiments now in progress, on the new conduit of the Boston Water Works, cannot fail to be of the greatest value in determining the co-efficients of flow in masonry channels.

The laws governing the flow of water in pipes, are still too little understood. It is a reproach to American engineers that so little effort is made to discover them, notwithstanding the opportunities presented by the pipe systems of our water works, sewage systems, and hydraulic mining conduits.

There is required, not only the collation and study of facts, but the generalizing faculty to invent new forms of expression, the existing formulæ, which come nearest to exactness, being too complicated for ordinary use.

In the treatment of the larger hydraulic questions, involving the flow of great rivers and their regulation, American engineers are prominent; both as regards the discussion of theories, and their practical application, and the names of Ellet, Humphreys, Abbot and Ellis, will at once occur to your minds, as those of engineers who have added to our knowledge on this subject.

Canals.

A list of the canals constructed in the United States, foots up 4 840 miles; of these some 300 miles have been abandoned.

The canal still awaits that improvement in its motive power which Stephenson accomplished for the railroad, by the invention of the locomotive; steam is yet to be successfully applied to the propelling of canal-boats. Quite a number of attempts have been made in this direction, but none have come into general use; and the latest of them, the design of Mr. Baxter, which was so favorably looked upon four years ago, and introduced on the Erie Canal, is understood not to have proved a financial success. It is possible that a fresh attempt, in a modified form would succeed better, but for the present attention is being directed to other methods.

The Belgian system is being tried this season, on the ninety-three miles of the Erie Canal between Buffalo and Rochester. This consists, as probably you know, in the laying of a wire rope or chain in the bed of the canal, to be fished up by the boat which wants to use it, and passed around the drum of a winding steam engine placed upon its deck; the working of which pulls the boat along the chain, and thus along the canal. This system has given economical results abroad, but many engineers think it can be improved upon.

The Nestor of our profession in this country, our Honorary member, Mr. John B. Jervis, who at the age of four score, yet preserves his clear intellect, and interest in engineering matters, proposed year before last to supply steam power to the towing of canal-boats, by drawing them with locomotives specially constructed for the purpose, and running upon

railroad tracks, to be laid on each bank of the Erie canal. He calculated that with an expenditure, then estimated by him at $7 524 000, the cost of towing could be reduced from 25.55 cents per mile to 10.50 cents per mile per boat, and that the time of a round trip from Buffalo to Troy and return, would be reduced from 17¼ to 13¼ days, or a saving of 4 days, the value of which he estimates at $37 04 per trip.

This should be tried, and it may be that it will allow of much greater speed than now obtains on canals, for I remember reading in an English review, an account of the extraordinary results obtained by Mr. Fairbairn in 1830, in some experiments on the Monkland Canal, which showed that while the resistance to the passage of a boat increased rapidly at a speed of 3 to 8 miles per hour, at a speed of 8 to 14 miles the vessel rose and skimmed over the surface of the water with a very much reduced resistance. But the cost of horse power at high speed opposed the prosecution of this plan on the score of economy, and Fairbairn's design of a light, swift canal-boat has not hitherto been carried out.

Railways.

Quick to appreciate the consequences of the invention of the locomotive, or rather its marvelous improvement by Stephenson in 1829, and the peculiar adaptability of the railroad to our country, as a means of settling up new lands and of cheapening the interchange of products, we began building railways very soon after the English, and have pushed their construction with unexampled vigor.

From advanced sheets kindly furnished by Mr. H. V. Poor, we have the following table of railway construction in the United States in each year since 1830.

STATEMENT SHOWING THE NUMBER OF MILES OF RAILROAD CONSTRUCTED EACH YEAR IN THE UNITED STATES FROM 1830 TO 1879 (DECEMBER 31).

YEAR.	MILES IN OPERATION.	ANNUAL INCREASE OF MILEAGE.	YEAR.	MILES IN OPERATION.	ANNUAL INCREASE OF MILEAGE.
1830	23	....	1855	18 374	1 654
1831	95	72	1856	22 016	3 647
1832	229	134	1857	24 503	2 647
1833	380	151	1858	26 968	2 465
1834	633	253	1859	28 789	1 821
1835	1 098	465	1860	30 635	1 846
1836	1 273	175	1861	31 286	651
1837	1 497	224	1862	32 120	834
1838	1 913	416	1863	33 170	1 050
1839	2 302	389	1864	33 908	738
1840	2 818	516	1865	35 085	1 177
1841	3 535	717	1866	36 801	1 742
1842	4 026	491	1867	39 250	2 449
1843	4 185	159	1868	42 229	2 979
1844	4 377	192	1869	46 844	4 615
1845	4 633	256	1870	52 914	6 070
1846	4 930	297	1871	60 283	7 369
1847	5 598	668	1872	66 171	5 888
1848	5 996	398	1873	70 278	4 107
1849	7 365	1 369	1874	72 383	2 105
1850	9 021	1 656	1875	74 096	1 712
1851	10 982	1 961	1876	76 808	2 712
1852	12 908	1 926	1877	79 147	2 339
1853	15 360	2 452	1878	81 841	2 694
1854	16 720	1 360	1879	86 121	4 280

Of which about 4 700 miles are narrow guage.

That this does not compare unfavorably with what has been accomplished in other countries, appears from the following table of the population and railways of the world, at the close of 1875, which I also borrow from Poor's excellent manual for 1876–1877.

RAILROADS OF THE WORLD.

STATEMENT SHOWING THE AGGREGATE OF THE RAILROADS IN EACH COUNTRY AND THE RELATION THEREOF TO AREA AND POPULATION AT THE CLOSE OF THE YEAR 1875.

Countries and States.	Area.	Population.		Railroads in Operation Miles.	Railroad Miles to	
	English sq. m.	Census or Estim. 1875.	Ratio, sq. m.		Area sq m.	Inhabitants.
United States of America	3 026 504	43 785 718	14 4	74 658	40.5	586.5
Dominion of Canada	686 353	4 941 690	7.2	4 488	152.9	1 101.1
United States of Mexico	829 916	8 133 719	9.8	327	2538.0	24 873.8
Total North America	4 542 773	56 861 127	12.4	79 473	57.2	707.3
Central America and West Indies	151 001	2 593 739	17.2	611	247.1	4 245.1
South America	6 401 777	22 137 700	3.4	3 826	1673.2	5 786.1
Total America	11 095 551	81 592 566	7 3	83 910	132.2	973 4
Europe	3 886 813	306 397 611	78.8	88 007	44.2	3 481.5
Asia	1 846 194	255 333 132	138.2	7 087	260.5	36 028.4
Africa	880 636	14 107 569	16 0	1 538	572.6	9 172.7
Australasia	2 406 070	2 235 079	0.9	2 148	1101.5	1 040.5
Grand total	20 115 261	659 666 957	32.8	182 690	110.1	3 612.7
World without the Railroad	31 220 246	730 365 043	23.4	……..	……	…….
World in gross	51 335 510	1 390 032 000	27.1	182 690	280.0	7 614.2

Since 1875, some 10 268 miles have been built in Europe, and about 5 000 miles in other parts of the world, outside of the United States, chiefly in Australia and India, so that the world's railways probably stand to-day as follows :

Europe...........	98 275	miles, or...........	47	per cent.
United States.....	86 121	"	41	"
Rest of the world..	25 000	"	12	"
	209 396			

Thus our 50 millions of inhabitants have furnished themselves with 86 000 miles of railway, while the 306 millions of Europe have 98 000 miles, and the 1 050 millions of the rest of the world possess but 25 000 miles.

There was in Great Britain on the 1st of January, 1879, 17 333 miles of railway, on which there were about 32 000 miles of track, 12 969 locomotives, 418 322 passenger and freight cars, owned by the companies, in addition to some owned by private parties, and over which trains ran 222 376 114 miles, and conveyed 565 000 000 passengers.

The capital account of the English roads was 698 545 154 pounds sterling, or \$3 380 958 545, thus giving an average cost of \$195 059 per mile of road.

The average cost per mile in several other countries about the year 1875, was as follows :

France..................	1873	\$152 500
Belgium..................	1873	111 342
Germany.................	1875	100 570
Austria-Hungary..........	1875	105 847
All Europe................	1875	120 960
United States............	1879	58 915

Thus our railroads have cost less than half as much per mile as those of Europe.

Going back one year, for purposes of comparison, on the 1st day of January, 1879, we had in the United States, 81 841 miles of railroad, on which there were 101 660 miles of track, or enough to encircle the globe three and a half times. There ran upon these roads 16 445 locomotives,

11 683 passenger cars, 4 413 baggage, mail and express cars, and 423 013 freight cars.

The capital invested was \$4 772 297 349, or \$58 915 per mile of railroad; the gross earnings were \$490 103 351, or \$6 209.52 per mile; the working expenses were 61.79 per cent. of earnings, or \$302 528 184—say \$3 887.10 per mile of railroad; and the net earnings were \$187 575 167—say \$2 322.42 per mile, or 3.932 per cent. on the nominal capital.

While the greater cheapness of our American railroads is in some measure due to the comparative smoothness of much of our country, and to the absence of heavy land damages, much more is due to the methods of construction applied to the railroads themselves, to the cheap and efficient expedients which our engineers have introduced, and especially to the character of the rolling stock which we have adopted.

The early locomotives obtained an adhesion and tractile power equal to $\frac{1}{14}$ of the weight upon their driving wheels. I believe that in other countries $\frac{1}{7}$ of the weight is even now considered a standard and satisfactory performance, while our American locomotives, including the latest type, the "Consolidation" engine, of 50 tons weight, regularly work up to $\frac{1}{5}$ in winter, and $\frac{1}{4.5}$ in summer, of the weight upon their drivers, with occasional performances up to $\frac{1}{3}$, and even less.

That is to say, if a locomotive has 88 000 pounds weight upon eight driving wheels, and obtains an adhesion of $\frac{1}{7}$, it will pull a train equal in resistance to the lifting of a weight of 12 571 pounds; while if it works up to $\frac{1}{4.5}$ in adhesion, it would pull 19 555 pounds, or 55 per cent. more under the same circumstances.

Not only do our locomotives pull greater trains than do European locomotives, in proportion to their own weight, but they run more miles in the course of the year: Stürmer's statistics for 1875, showing that the average train mileage for locomotives (not the engine mileage, but the mileage of passenger and freight trains, divided by the whole number of locomotives), was for all Europe, 15 720 miles per year, and for the United States, 21 900 miles per annum.

This has been accomplished by a series of improvements in construction, which have brought our locomotives materially to differ from their European prototypes, and which fairly entitle us to speak of them as American in design.

These improvements chiefly consist: First. In the substitution for a rigidly attached pair of leading wheels, of a four-wheeled truck pivoted

at its centre, or of a swing-beam pair of wheels, under the front end, thus allowing lateral play, and giving the engine great ease in passing curves; and, also, Second. In the connecting together of the driving wheels and axles, with one or more pairs of equalizing levers, to distribute the weight among them, and thus keep its apportionment nearly constant, while the wheels are free to follow and adapt themselves to all the irregularities and deflections of the track.

These two features, together with careful counterbalancing and easy springs, have not only given our locomotives great ease and steadiness of motion, even over rough tracks, but have made them more efficient over good tracks. Moreover, outside cylinders and accessibility of parts, give great facility for repairs, and notwithstanding the higher prices which we pay in this country for labor and materials, our American locomotives are cheaper to build and to maintain than those of foreign makers.

This efficiency in the motive power has enabled us to cheapen greatly the construction of our roads, by locating them with sharper curves and steeper grades than would otherwise be possible, as is evidenced by the comparison of cost per mile already given.

There are, however, a number of features of European locomotive practice, which it would be well for us to study, and possibly to imitate, such as improved methods of boiler construction, economy of fuel, and better proportion of heating surfaces.

By calling attention to these, the editors of the *Railroad Gazette*, from whom many of the statistics hereafter to be given have been obtained, are doing the country, as well as engineers, a good service.

We have applied to railroad cars similar features of flexibility and diminished resistance, by placing under each end a pivoted truck of four wheels, instead of a single pair of wheels rigidly attached. This arrangement enables us not only to shorten the wheel base, but to lengthen the car. It passes with ease around curves even as short as 100 feet in radius, and improved design and workmanship, together with our tight journal boxes, lubricated with mineral oils, have reduced the resistance of cars so much, that recent experiments made upon several of our roads, indicate a rolling friction of only 4 or 5 pounds per ton, *on a level straight line at low speed*, or only one-half of the co-efficient as given in all engineering note books.

Until recently, the proportion of live or paying weight carried by our

freight cars, did not as well compare with their own dead weight, as in European freight cars. The latter, with four wheels, generally weigh 13 000 pounds, and carry 20 000 pounds when fully loaded. It took us a long while to realize that having started with 8 wheels under our cars, we could, by increasing their weight in some degree, at the same time increase their carrying capacity in still greater ratio, and so obtain better proportions. The more recent freight cars, however, those of the Pennsylvania Railroad, carry 40 000 pounds, and they weigh about 21 000 or 22 000 pounds, if built as box cars, and 19 000 pounds, if constructed as coal cars; the latter especially, being exceedingly well designed.

And since I have mentioned the name of the Pennsylvania Railroad, allow me to call the attention of the members of this Society to the study and imitation of that splendid work, which, if not the most perfect, is certainly one of the most perfect railroads in the world. The expenditure of money, and thought, and care, which has been going on upon it for many years, has reduced the cost of transportation over it, to less than obtains on any other trunk line which crosses the Alleghany range.

There are two features of European practice, which, perhaps, it would be well for us to introduce in our freight cars. The first is the substitution of iron for the wooden sills, which now form their foundation. The second is the larger use of platform and gondola cars for carrying freight. Even dry goods and groceries, covered with tarpaulins, are carried on flat cars in England, where it rains much oftener than it does here; and the ease and cheapness with which these cars are loaded and unloaded (with proper appliances) in comparison with our box cars, promises a notable economy of station labor.

We also continue to handle all goods at our depots with hand labor. At all stations where traffic is large, we might substitute machinery to advantage for many classes of freight. This offers a fine field of invention and adaptation for engineers or mechanics.

While paying much attention to cheapness in the transportation of freight, and obtaining results, as we shall see hereafter, which compare favorably with those obtained elsewhere, we have not been unmindful of the safety of passengers. Our safety platforms and power brakes, together with the extended use of the telegraph, have made traveling in this country generally as safe as it is abroad, notwithstanding the lighter character of our roads, and the fact that most of these are single tracked.

We have, however, much to do, particularly in introducing signals to control the movements of trains. This is done almost universally in Europe, and scarcely at all in this country. Not only is traffic comparatively light on many roads, but with us labor has been so expensive, that we have hesitated at adopting the block signals which require the attendance of numerous men. American inventors have turned their attention instead to automatic signals, of which there are several systems which promise well. It is to be hoped that they will be so improved, perfected and cheapened as to lead to their adoption.

Although our railroads were originally cheaply and imperfectly built, and although we pay in this country a great deal more for labor and material than the prices which obtain in Europe, we have nevertheless reduced the cost of transportation to as low figures, if not lower, than any which obtain on the other side of the ocean. The grindstone of competition between the railroads themselves, and with canal, river, and lake routes, has reduced freight transportation to such a fine point, that our railroad managers have devised new and cheaper methods of doing their work, have learned to operate their roads with a smaller proportion of men, and have accomplished results which astonished even themselves.

It is difficult to make comparisons of rates and costs between different railways, because scarcely any two of them are placed under precisely the same circumstances, but it is known that the lowest rates in England are given on mineral traffic. This is understood to be about $\frac{7}{8}$ of a cent a ton a mile, while the regular rate from Chicago to New York, upon domestic produce (grain, flour, provisions, lard, etc.,) is now $\frac{5}{8}$ of a cent a ton a mile, and in times of sharp competition has been $\frac{2}{10}$ of a cent a ton a mile.

The English railroads do not report their earnings and expenses per ton per mile, but the German Union railroads (which include about 27 000 miles in Germany, Austria, and Hungary, as well as some in Belgium and Holland,) do, as well as the Belgian state railroads. In the table which follows, the freight revenue, expenses, and profits of these are given for such years as were accessible, and for purposes of comparison, similar figures are given for the railroads in such American States as report the necessary data, as well as for a number of individual American railroads, of which the revenue and expense, per ton mile, have been published in the *Railroad Gazette*.

RAILWAYS.	YEAR.	REVENUE. CTS. PER TON MILE.	EXPENSE CTS. PER TON MILE.	PROFIT. CTS. PER TON MILE.
German Union R. R..........	1875	2.100	1.194	0.906
" "	1876	2.070	1.154	0.916
" "	1877	2.050	1.094	0.956
Belgian State R. R............	1877	1.431	0.856	0.575
State of Ohio.................	1876	1.117	0.801	0.316
" Michigan	1878	1.053	0.632	0.421
" Illinois..............	1879	1.028	0.617	0.411
" Massachusetts........	1879	1.838	1.066	0.772
" New York............	1877	1.059	0.781	0.278
" "	1878	0.999	0.690	0.309
N. Y. Central.................	1879	0.796	0.541	0.255
Erie	"	0.780	0.561	0.219
Pennsylvania..................	"	0.824	0.480	0.344
Boston & Albany.............	"	1.073	0.622	0.451
Pitts., Cin & St. L...........	"	0.720	0.420	0.300
Col., Chi. & Ind. Cent,........	"	0.700	0.590	0.110
Vandalia Line.................	"	0.931	0.715	0.216
Mich. Central.................	"	0.692	0.407	0.285
Lake Shore....................	"	0.642	0.398	0.244
Clev., Col., Cin. & Ind.........	"	0.697	0.575	0.122
Chicago & Alton..............	"	1.054	0.558	0.496
Illinois Central...............	"	1.520	0.640	0.880
Chi. Mil. & St. P..............	"	1.720	0.941	0.779

Thus, it will be noted, that the profit alone on freight is more on the German Union Railroads than the gross receipts of the three American trunk lines, and although it is true that the passenger rates are materially lower in Germany than they are in the United States, yet if the traffic of the New York roads had been carried at the German rates for 1877, the profit alone would have been $52 500 000 more than it was; if carried at the Belgian rates, both for passenger and freight, the profit of the New York roads for 1878 would have been more by $13 000 000; that is to say, twelve millions less upon passenger, because of the lower Belgian rate, and twenty-five millions more on freight than it was, and

these sums may fairly be said to have been saved to the public by the economical operations of our roads.

In fact, sharp competition and the incessant demands of the public, have for the past few years diminished rates so rapidly, that, as a whole, our railroads are now paying smaller returns upon the entire capital invested in them than those of most of foreign countries, and the people of the United States have since 1873 had their property transported for less than it was reasonably worth. It has been shown in giving the net earnings of all our railroads, that for the year ending January 1, 1879, they earned 3.93 per cent. upon the total capital invested in them, while the railroads of Europe in 1875 earned the following returns upon their capital :

Great Britain	4.4	per cent.
France	5.1	"
Germany	5.1	"
Austria-Hungary	3.9	"
Russia	4.	"
All Europe	4.3	"

It may be claimed that the capital of our American roads exceeds their real cost, in consequence of what has been called the watering of the stock of some of them ; but it is believed that much larger sums than those so added to the stocks of the successful roads, have been wiped out and lost in the reorganization of the unsuccessful roads, so that this return of 3.93 per cent upon the entire capital of all our roads seems an insufficient return in a country where money brings six to twelve per cent. interest. If, therefore, railroads are to continue to grow (and as only about one-half our territory is as yet provided with them, we shall doubtless have many more miles to build as population increases), it may be necessary that the reduction of rates shall be arrested for a while at least. They have been reduced not less than 56 per cent. in the State of New York, and about 45 per cent. in the State of Massachusetts, between 1868 and 1877, while in the German Empire during the same period they were only reduced 22½ per cent.

As Americans, we have no reason to be dissatisfied with the results accomplished thus far. We have succeeded in so organizing labor, that while we pay it from 30 to 50 per cent. more than in Europe, we build our railways for about one half the cost, and we transport freight over

them, with the aid of our machinery, at materially cheaper rates than those which obtain in other parts of the world.

Not only should engineers endeavor still further to improve and to cheapen the construction, and especially the operation, of our railroads, but they should now find in foreign countries, as yet unprovided with them, fields in which they can introduce the features of economy which we have developed.

At home we shall doubtless continue to build new lines in the same cheap, light style which we have made so efficient, and we shall largely extend the narrow gauge in sparsely settled districts. We should, however, so locate our roads as to secure the best possible line and gradients, even if after they are adopted, we do not bring the embankments to the full heights, in order to save present expense. As population and traffic increase, we can, if the works are well planned for that purpose, rebuild, add to and improve them, so as to diminish the cost of transportation, to the best economy.

Street Railways.

While we have been extending steam railways through almost all parts of our country, we have also endeavored to avail ourselves of diminished traction, by laying tracks down in our cities to be operated by horses. It is estimated that there are now about 3 500 miles of horse railways in the United States, and considerable additions are in progress.

Transportation by horses is slow, however, and the want has been felt in several of our cities of some method of using steam power as a motor, to increase the speed and diminish the cost. This has been accomplished in London by the building of underground railways, which, however, as they cost about a million and a half of dollars a mile, can only be introduced where the traffic is very large. In New York the problem has been solved by building elevated railroads which run upon girders supported above the streets by iron posts, and which cost about $300 000 per mile.

In order to avail of this method of rapid transit in other American cities, a decided reduction in the cost of the structure will perhaps be necessary, and several engineers are now devising and endeavoring to introduce cheap structures for that purpose.

Bridges.

While it is true that bridges were built centuries before engineering was recognized as a distinct profession, it is true equally that engineers, admittedly to-day, are the bridge builders of the world. Our predecessors of earlier days worked in wood and stone, and their rules of construction were founded upon the cut and try method. We have now added iron and steel as constructive materials, and it becomes a part of our duty to determine upon scientific principles the proper distribution of strains, and the due proportioning of materials to resist them, so as to secure the greatest amount of efficiency at the least cost.

As a temporary expedient, wooden bridges were early built in this country, under the familiar names of the Burr truss and the Town lattice, but after the introduction of railroads, it became necessary to provide a more efficient system of counter bracing, than could be attained in the earlier forms of trussing. The Howe truss was invented, and was found to be the simplest and best arrangement that could be adopted. This bridge is undoubtedly the best of its kind in the world, and has been of immense service in facilitating the development of our railway system, through what may be called its pioneer stage. From data obtained in the railroad reports of the States of Pennsylvania and Ohio, it is estimated that there are now in the United States about 900 miles of bridges upon our railroads, of which, perhaps, one-third are permanent structures, of stone and iron, and two-thirds at least are temporary structures of wood, which will have to be rebuilt by our engineers.

The demand for more permanent structures has brought about the substitution of iron for wood. As might have been expected, the forms of trussing with which we were most familiar in wood, were the first upon which experiments were made in iron; while, however, our English brethren 30 years ago were building plate girders and tubes, our venerable Honorary member, Squire Whipple, was studying the subject, and with characteristic modesty, laying down the principles of a science of bridge construction based upon determining the action of the forces, in skeleton structures, by rigid mathematical calculation. His book, printed by his own hand in 1847, contains nearly all that is vitally important connected with the theory of fixed spans, and his bridges stand to-day as monuments to his skill, and reminders to us of the debt we owe to that distinguished engineer.

The concentration of the material into a few parts resulted in the use of the pin connection at the joints, in contradistinction to the rivet, as used in other countries. For compression members, cast iron very readily adapted itself to top chords and posts, and until late years, was considered satisfactory.

To resist tension, it became necessary to forge bars with enlarged heads, now known as eye-bars, and to determine the proper proportion of pin and eye, to the section of the bar, so as to develop its full strength. In this we have been reasonably successful, and with the introduction of improved machinery, we have been enabled to make and secure uniformly reliable bars at a very low cost. To this fact, perhaps, more than any other may we attribute the success which has attended the labors of American bridge builders.

The eye bar is the distinctive feature of the pin connected bridge, and upon it depends in a large measure its economy.

A bridge which can be taken upon the staging in pieces and made self-sustaining, between daylight and dark, would seem to need little more to be said in its favor, as compared with the tedious and expensive methods, rendered necessary in the erection of riveted structures.

It must not be assumed, however, that American bridges are all pin connected. Many of the best railroads in the country prefer riveted bridges on account of their superior rigidity, particularly in short spans, and from the fact that they are not easily knocked down by derailed cars, a point which has not received that attention which it deserves. Our shop practice in riveted work is generally good, and we have effected some improvements on the European methods, in general design ; but we are yet deficient in experimental knowledge as to the value of the rivet connections, particularly when applied on one side of an angle bar, and we have not yet been able to avoid cross strains upon the chords, at the intersection of the diagonals.

The English practice of drilling all holes on the ground where splices occur, has not been found necessary here, when a proper system of automatic spacing is employed.

The chief defects in our bridges have arisen from the weakness of the floor, and when it is remembered that locomotives have increased in weight within the past few years about forty per cent., and that the floor is subjected to its maximum strain every time that a locomotive passes over the bridge, it will be apparent that a decided increase in strength must

be given to this portion of the structure, and in all probability it will be necessary to renew many of our earlier bridges in this particular.

Again, there should be more efficient provision against disaster from the derailment of cars. The less wood we have on iron bridges the better; ties are, of course, a necessity, but they should be supported on at least four iron stringers, and be spaced 8 to 10 inches apart, and secured against spreading. Joint boxes should be avoided. End posts should be continuous to the masonry supports, and secured to the top chords, and to each other by efficient portals. Horizontal bracings, to resist vibrations and wind pressure, should be made more effective than they are, particularly at the chord connections. There are many other minor details, it is safe to assume, which will be perfected in due time, but upon the broad question of experimental information, we must look for aid to every member of the profession.

A testing machine of the very best description, belonging to the United States Government, is now in working order, at the service of all such as may desire to avail themselves of it. I believe the time has arrived when a committee of this Society should be appointed for the purpose of inviting the co-operation of manufacturers, in the effort to obtain more accurate knowledge of the metals and manufactured shapes which enter into our important structures.

Particularly is this the case in regard to the material which we call steel. Of late, the manufacture of steel by the pneumatic and open hearth processes, has been undergoing a prodigious development, and we may now assume that a metal can be obtained by either of these methods, more uniform in its character than the best iron yet offered in merchantable quantities; possessing an elastic limit of 40 000 pounds per square inch, and an ultimate strength of 65 to 70 thousand pounds per square inch, and capable of being manufactured into any of the required shapes for structural purposes, at a cost which, taken in connection with the saving involved in dead weight, must ensure its substitution for iron in the larger spans at least; and it is confidently asserted by those whose experience entitles them to speak with authority, that the day is not far distant when steel will be produced at a less cost than iron is at present by the hand puddling process.

All the more important, therefore, is it that we should inform ourselves by the most thorough tests of the characteristics of steel, if we would maintain the high standard of American bridge construction.

We have thus far applied this metal to but few structures. It has been used in the bridge at St. Louis, in the bridge at Glasgow, and is now being used in the East River Bridge, designed by Mr. Roebling, of 1 600 feet span, and in parts of the Plattsmouth Bridge, which you are invited to visit. It is hoped that the engineers of these pioneer structures will communicate to the Society the information which their experiments have elicited concerning this material of the future.

The day cannot now be far distant when the merits and economy of the American type of bridges will be recognized by other nations. Already, notwithstanding the fact that labor and materials are cheaper in other countries than in this, we are enabled to compete successfully in Canada and in South America. I believe that a well directed effort to make known abroad, what we have accomplished in this branch of engineering during the last fifteen years, would open a market for our bridges and bridge designs in Europe and in Asia.

Preservation of Timber.

The rapid disappearance of the forests in this country, and the consequent growing scarcity of timber, point to the necessity of sooner or later adopting some method of wood preservation.

Several processes have been in use in Europe for many years, with satisfactory results, but in this country success has not been the rule. Whether these failures have been due generally to imperfect preparation, or because we have blindly followed the foreign methods, without modifying them to meet the different conditions here, we are not prepared to say; but the whole question is so important that a report of our failures even more than that of our successes would be of great value to engineers.

It is hoped that all of those members of this Society who have had any experience whatever in this line will communicate the results to the standing committee, which has been appointed during the past year to investigate the subject of wood preservation.

River Improvements.

We have as yet done little toward regulating and improving our rivers. Blessed with a magnificent system of internal navigation, which, as Mr. Fink and Mr. Blanchard have recently shown, virtually

compete with and regulate freight upon almost all of our railroads, we have directed our attention rather to the craft that navigate them than to the streams themselves.

The further demand for cheaper transportation, however, as well as the higher spring floods and the lower summer waters, which come with the destruction of the forests, make it necessary that we should within a few years begin extensive river works. Colonel Mason, late member of this Society, showed us in building the St. Joseph Bridge that even the Missouri River was easily controlled, and made to flow wherever the engineer desired, by throwing out cheap and apparently frail brush dykes. A much greater and more original work has since been accomplished by the same simple means by our distinguished member, Captain James B. Eads, who, taking in hand the smallest and most unpromising pass of the Mississippi River, with seven feet of water over its bar, has in four years transformed it into the best access from the river to the sea, with thirty feet of water over the bar, at the cost to the nation of only $5 250 000, while the ship canal which had been proposed by other parties was estimated to cost $10 000 000.

The same far-seeing engineer is now engaged in studying the remainder of the course of the Mississippi River, and devising plans for its control and improvement. You have probably read the report to Congress of the board on which he has been acting, in which, differing widely from their predecessors, they propose to regulate the depth and flow of the river, by reducing its width at those points where it spreads into shallow sand bars.

The reasons by which these proposals are supported seem so sound, that it is to be hoped our Government will soon take steps to test the efficacy of the proposed methods upon an adequate scale.

The first of what is likely to prove a series of works to control the low water discharge of our rivers is being built upon the Ohio River at Davis' Island dam, five miles below Pittsburgh. It is a movable dam, of which you will find a brief descriptions in *Scribner's Monthly Magazine* for this month (May, 1880).

The French have preceded us in works for regulating the flow of their navigable rivers, and have designed a number of types of moveable dams (which they call "barrages"), which are well worthy of study and possibly of imitation. We shall doubtless make some changes, and perhaps improvements in them, to adapt them to our necessities, and to

our constructive methods; and this class of works should hereafter attract the study and attention of the members of our profession, more than has been the case hitherto.

The boldest and most interesting harbor work now being carried on by our Government is probably the removal of the rocky obstructions in the East River of New York, at Hell Gate.

General Newton, as you know, sank a shaft in the rock at Hallett's Point to a depth of some 50 feet below low water, honeycombed the rock with 7 426 lineal feet of galleries in various directions, and charging 4 427 drill holes in the remaining pillars and roof with 49 915 pounds of "rend rock," "vulcan powder" and "dynamite," blew up the whole Point, extending over three acres, and containing 63 135 cubic yards of rock, on the 24th of September, 1876. So accurately were the explosives located and proportioned, by the mathematical formulæ worked out for the occasion, that not the slightest damage was done to the surrounding houses and premises. The debris has since been removed with a grapple to a depth of 26 feet below low water.

General Newton is now engaged in undermining in a similar manner the rocky island of eight acres (mostly under water) known as "Flood Rock," in the same vicinity. He has sunk a shaft, and driven, to May 1, 1880, 5 273 lineal feet of galleries, from which he has removed 19 044 cubic yards of rock, leaving a roof varying from 8 to 19 feet in thickness between the top of the galleries and the water in the tide way, which is from 6 to 12 feet deep.

The holes are all bored by machine drills driven by compressed air.

Light-houses.

From the report of the Light-house Board for the year ending June 30, 1879, it appears that the Government has erected the following light-houses:

First order	47
Second "	26
Third "	55
Third and a-half order	10
Fourth "	200
Fifth "	123
Sixth "	165
Total	626

River lights—Mississippi, Ohio and Missouri Rivers....................................	737*
Buoys in position....................................	3 114
Fog signals—steam or air....................................	56
Light ships....................................	31

As a measure of comparison, it may be interesting to note that on the 31st of December, 1878, England reported 597 light-houses and France 346 light-houses.

Many of the 626 reported by the Light-house Board are doubtless temporary structures, and they will have to be renewed; but in the meantime they are rendering good service to navigation, by lighting our coasts and harbors.

Marine Engineering.

Our vessels engaged in foreign trade which had gradually increased to an aggregate tonnage in 1861 of 2 642 628 tons, have dwindled away ever since, until in 1879 they comprised but 1 491 533 tons. These consisted of only 168 steam vessels, measuring 156 323 tons, and 2 549 sailing vessels, measuring 1 335 210 tons.

The tonnage movements of our ports showed that in 1879 the entrance of American vessels engaged in foreign trade aggregated 3 049 743 tons, so that they averaged a little over two trips per year, while the tonnage of foreign ships entered was 10 718 394 tons, or 3½ times our own.

Originally caused by our civil war, the continuance of this decay of our marine engaged in foreign trade, is attributed to a concurrence of two principal causes: First, the substitution of steam for sailing vessels in the commerce of the world, consequent upon the improvement in ships and compound engines made by the English, and secondly, the demonstration that iron vessels are more economical in operation than wooden ones.

Mr. Joseph Nimmo, Jr., Chief of Bureau of Statistics, says, in his report for 1879, "The tonnage of iron vessels built in this country during the last five years amounted to only 97 872 tons, whereas the iron

* These lights mainly consist of lanterns suspended from wooden scaffolding easily moved; their position is shifted to correspond to the shifting of the channel. They have given such great satisfaction to those interested in river navigation that they are now regarded as indispensably necessary.

ship building of Great Britain during the last five years reported, amounted to 1 927 710 tons. * * *

"Probably no other branch of American industry comes so directly into competition with foreign industries, as do those of building vessels, and operating them in international commerce. * * *

"So long as wooden sailing vessels were the only vehicles of commerce upon the ocean, American tonnage rapidly increased. * *

"The United States had, about the year 1850, attained nearly to the first rank among the maritime nations of the globe. * * *

"The change from wooden to iron vessels began to take place about the year 1857. * * *

"The difference between the cost of building iron vessels in this country and in Great Britain is much less at the present time than it was ten years ago. This is chiefly due to the reduction in the wages of labor and in the price of materials in the United States." * * *

Thus, in our foreign marine alone, of all our industries have we lost ground. Although Fulton, an American, was the first to apply steam to navigation; although an American steamer, the Savannah, in 1819, was the first to cross the ocean, we have not only failed to keep our position in foreign shipping, but we have lost numerically, and our tonnage has actually dwindled away.

The diminished difference above noted between the cost of building iron ships in this country and in Great Britain is believed not to be wholly due to reductions in wages, and in the price of materials; much of it is attributed to improved organization in our ship yards, and to labor-saving appliances. It is believed, that more remains to be done in the same direction.

Here, then, is a splendid field for our marine engineers and ship builders. Let them accomplish for the iron or steel steamer what has been done for the railway, the locomotive, and the iron bridge; and so improve the design, the proportions, the framing and machinery of the ships, as well as the organization of the labor engaged in their construction, as to do their work, by the aid of machine-tools, and a judicious system of piece work, so cheaply as to enable us to overcome the difference in the cost of labor, and take again our proper rank upon the ocean.

The marine engaged in our internal navigation, and coasting trade,

has, however, nearly maintained its position, notwithstanding the extension and competition of the railroads.

Arriving at a maximum of 2 897 185 tons in 1861, it still aggregates for 1879 2 678 067 tons, of which 1 019 848 tons are propelled by steam. It consists of 13 085 sailing vessels, measuring 804 688 tons, engaged upon the Atlantic and Gulf coasts, and on the Pacific coast; and of 1 408 sailing vessels, measuring 282 916 tons, upon the northern lakes.

There are also upon the northern lakes 868 steam vessels, measuring 194 416 tons, together with 170 barges aggregating 42 226 tons, and 548 canal-boats* aggregating 44 774 tons.

On our rivers which empty into the Atlantic and Gulf coasts there are 2 067 steam vessels, measuring 499 002 tons; 764 barges, with 159 041 tons, and 658 canal-boats*, with 58 963 tons.

On the rivers which empty into the Pacific we have 267 steam vessels, measuring 77 050 tons, and 87 barges with 14 596 tons.

While on our western rivers there are 1 199 steam vessels aggregating 249 380 tons, and 1 373 barges, with 251 015 tons.

Thus it will be seen that of our domestic tonnage, 4 401 vessels out of 22 504, and 1 019 848 tons out of 2 678 067 tons are propelled by steam, and this proportion of steam vessels engaged in our domestic trade, as well as the comparatively short distances over which they ply, enables them to move many times the aggregate tonnage of our foreign trade.

This domestic steam marine presents nearly every variety of practice, from the coasting steamer and the lake propeller, to the western steamboat, some of them of such light draft that it used to be said that they could run on a heavy dew. Our daily experience proves how well adapted the vessels are to our requirements, and the civil war showed that they could be made effective in supplementing a weak war navy.

One engineer, still living, has contributed more than any other to this great advance. I refer to Captain John Ericsson, he, who competed with Stephenson in 1829, and built the locomotive "Novelty," which only failed, by the breaking of a part of her machinery, from carrying off the first prize; who, in 1837, designed and placed on the Delaware and Raritan Canal, the first screw propeller ever in actual service; who

* As under existing laws very few canal-boats are enrolled and licensed, only those which come out of canals, and navigate naturally navigable waters, are included in the above list which is taken from the reports of the Bureau of Statistics.

designed and built, in 1844, the frigate Princeton, the first steam war ship of the United States, and has since given us the hot air engine, a surface condenser, a vibrating piston and crank applied to marine engines, a deep sea sounding lead, a gun carriage and a compressor to resist the recoil; who sent down to Hampton Roads, in 1862, the "Monitor" to turn the fortunes of the war, and who, still keeping up, in his old age, his incessant labors, is now engaged in investigating and inventing a new motor, the power of which he proposes to derive from the sun, while he is designing and building his new ship, "The Destroyer," which he expects to sink all war ships she may attack, to the bottom of the ocean.

Telegraphic Engineering.

The lines of telegraph are being extended so rapidly that it is difficult, even for their owners, to state the aggregate quantities at any particular time.

The best information, however, which can be obtained is that on the 1st of January of this year, there were 119 042 miles of telegraph lines in the United States, and 299 859 miles of wire, without counting those lines specially used by the Gold and Stock Telegraph, and the District, the Fire Alarm and Burglar Alarm Telegraphs in the various cities.

One telegraph company alone, the "Western Union," had in June, 1879, 8 534 offices, from which were sent and received 25 070 106 messages during the preceding year.

Equally prompt has been the application of the telephone, which looked upon doubtfully, or only as a toy, when it was first shown by Professor Bell at our Centennial Exhibition four years ago, has so rapidly become a necessity, that there are now in this country 121 000 instruments at work, connecting our business places and dwellings with each other, and with the central offices, by means of which we are almost instantly brought within speaking distance of the persons, miles away, with whom we have to transact our business.

You are so familiar, however, with the telegraph and telephone, that it may be more interesting to you to call your attention to some of the house uses of electricity, which are becoming part of our common life. Within the last few years we have been introducing electricity into our houses, and virtually made of it a new domestic servant, by what are called the burglar and fire alarm systems; not only does it ring bells, and summon

the other servants, (and in recent appliances, keep these bells ringing until the summons are answered), but as a burglar alarm, it is on the watch at night, and in a house properly fitted with these contrivances, the whole or any part can be attached or detached at pleasure. The windows may be left partly open at top or bottom for ventilation, if desired; and once the current turned on, any attempt to alter their position, or to effect an entrance from the outside, causes an alarm which can be stopped only by the person in charge. A glance at the annunciator determines the position of the burglar, or by pressing a knob at the instrument, it shows what doors or windows are open. To accommodate late comers, the front door can be disconnected, or with a special key it may be opened without causing an alarm. In the absence of the family the bell may be made to ring outside, or in a neighbor's house, or at the Police Headquarters; while the clock that calls the servants in the morning, at any hour desired, disconnects such parts of the house they are allowed to use, so as not to disturb the rest of the family.

Applied to safes in counting-houses, or to stores containing valuable goods, the burglar alarm rings the bell at Police Headquarters, and at the same time indicates the point of attack. In a recent case in New York, the burglars, who had broken into a silk house, so promptly set off the alarm, that they were surrounded by the police and captured, as they were taking the goods down from the shelves. The system is being rapidly introduced in stores, counting and banking houses, and in connection with time locks on the safes, affords such good protection as to make watchmen almost superfluous.

Applied to fire alarm, electricity renders still more important domestic service; not only does it advise all the fire engines located in a particular district, whenever an alarm is sounded from a street corner, but it sets machinery at work which unhitches the horses from their stalls, wakes up the firemen (and tumbles them out of bed in some cities), harnesses the horses, lights the fires, and opens the doors of the engine house, so that the machine is ready to start in eleven or twelve seconds after the alarm is sounded; but the fire alarm is also extended to private houses, and there presents itself in the shape of three unobstrusive knobs. Push the first and you summon the fire department; touch the second and a police officer makes his appearance; press the third and a messenger comes to run your errands. Moreover, by means of the Pyrostadt, should a fire break out during your absence, the expansion of a

metallic bar makes an electrical connection, which sets off the alarm and summons the fire engine. It is believed that these and other uses of electricity are about to be largely extended in our country, and several members of our Society have lately turned their attention to them.

Gas Engineering.

Another department of engineering represented in this Society has for its object the construction and management of works devoted to the manufacture of illuminating gas.

In 1850 there were only about fifty gas light companies in the United States. In the thirty years which have elapsed since that time, the number of companies has increased to nearly nine hundred, with a capital aggregating more than two hundred millions of dollars. The amount of gas annually manufactured for illuminating purposes is probably not less than twenty thousand millions of cubic feet. The magnitude of the business may, perhaps, be better comprehended from the statement that this entails the mining, transportation, handling, and carbonizing of something over two millions of tons of coal per annum.

The gas makers, however, unlike railroad managers, have not until recently been compelled, by sharp competition, to study close economy, but the pressing demand for a reduction in the price of illuminating gas to the consumer is, to-day, necessitating the application of scientific education in all the departments of its manufacture.

The improvements that have been made thus far have consisted mainly in the setting of the retorts, and in more efficient condensation and purification. The competition brought about by the introduction of other illuminating agents is compelling the attention of engineers to the application of machinery, in the various operations involved in gas making, for the purpose of reducing the cost of labor and also developing the useful application of the various residual products, which result from its manufacture.

In other countries than the United States, particularly in England and France, the value of these residual products, together with the lower price of labor and material has enabled the companies to reduce the price of their gas much below the point at which it can be profitably sold

in this country. In the city of London the sale of residual products returns to the companies sixty-six per cent. of the cost of their coal. When the demand for these products increases to that extent in this country, a very decided reduction of the price of gas to the consumer can be made without reducing materially the profits of the companies.

The most recent application of the results of scientific investigation consists in the introduction of gas furnaces, and of mechanical means for charging and discharging the retort.

In gas furnaces very decided success has been reached not only by foreign engineers but by engineers in this country. The efforts that have been made in mechanical stoking, have heretofore resulted only in partial success, but within the last year a machine has been invented and put into practical operation in the city of Cincinnati, which bids fair to accomplish the desired result.

Much attention has been paid of late to what is called water gas, which consists, in principle, of the decomposition of steam by means of incandescent fuel, the resulting products of which are carburetted with petroleum to give it illuminating qualities. Claims of superior cheapness have been made by the promoters of this process, while coal gas makers claim that gas can be made from coal as cheaply as by any of the water gas processes. As the latter have been largely introduced in some places, time will undoubtedly show which party is entitled to the greatest amount of credence, but as yet by far the largest proportion of illuminating gas sold in this country is made from coal.

Metallurgy and Mining.

The growth of metallurgical and mining industry in the United States has been indeed gratifying. I fear that bare statistics will fail to convey an adequate idea of what has been accomplished, but I will give them to you notwithstanding.

And first as to that most useful of all metals, iron : The reports of the Iron and Steel Association show that, beginning in 1721 with six furnaces and nineteen forges, we now have 228 anthracite blast furnaces, 203 furnaces which use bituminous coal and 266 charcoal furnaces, or 697 completed furnaces in all, which are stated to have, if all were in blast together, a capacity of making 6 500 000 tons of pig iron a year.

We are now the second iron producing nation in the world, England being the first and Germany the third, while 44 new furnaces are reported as being built. We have in addition 382 rolling mills and steel works, containing an equivalent of 4 467 single puddling furnaces, 2 419 heating furnaces, and 1 397 trains ot rolls, with a capacity of four millions of tons a year in finished iron. Seventy-three of the rolling mills have nail factories attached, with 4 152 nail machines, and to make the list complete, we may add that there are in addition 69 forges, with a capacity of 85 000 tons a year, and 59 bloomaries, with a capacity of 80 000 tons a year.

From an advance copy of the Report of the Iron and Steel Association for the current year, kindly furnished by the Secretary, Mr. James M. Swank, I am enabled to give you the summary of the production of iron and steel in the United States during the past eight years : (see opposite page).

Mr. Swank says in his report : "Our steel industry is now the second in the world in productive capacity, and in a year it will pass that of Great Britain, and take the first rank. The increase within the past year in the capacity of our Bessemer and open hearth works, either completed or projected, is equal to an addition of 50 per cent. to the capacity which existed in 1878."

We now have eleven Bessemer works in the United States and two works are building. These contain twenty-two completed converters, and ten are building. We have a present capacity of 1 250 000 tons, and will have a capacity when the additions are completed of 1 750 000 tons a year, or enough to lay or to relay about 18 000 miles of railroad per annum.

The 22 completed converters have an aggregate capacity of 141½ tons, so that to produce the estimated output of 1 250 000 tons they must average 13.38 blows a day for 300 days in the year. While at work the converters average over 25 blows a day, while as many as 58 have been obtained from one vessel in 24 hours. Results which are thought to be much in advance of the average foreign practice, and which are chiefly owing to the labors and the skill of Mr. A. L. Holley, member of this Society, and the Consulting Engineer to all the Bessemer works in this country.

General Summary of the Production of Iron and Steel during the past Eight Years.

The appended table shows in tons of 2 000 pounds the production of all kinds of iron and steel in the United States from 1872 to 1879. In nearly all the branches of the domestic iron and steel industries which are here enumerated there has been an increased production in 1879 over 1878, and in most of them a very considerable increase.

Products.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.
Pig iron	2 854 558	2 868 278	2 689 413	2 266 581	2 093 236	2 314 585	2 577 361	3 070 875
All rolled iron, including nails and iron rails	1 847 922	1 837 430	1 694 616	1 599 516	1 509 269	1 476 759	1 555 576	2 047 484
All rolled iron, including nails and excluding rails	941 992	1 076 368	1 110 147	1 097 867	1 042 101	1 144 219	1 232 686	1 627 324
Bessemer steel rails	94 070	129 015	144 944	290 863	412 461	432 169	550 398	683 964
Open-hearth steel rails	....	....	....	....	....	....	9 397	9 149
Iron and all other rails	905 930	761 062	584 469	501 649	467 168	332 540	322 890	420 160
Rails of all kinds	1 000 000	890 077	729 413	792 512	879 629	764 709	882 685	1 113 273
Kegs of cut nails and spikes, included in all rolled iron	4 065 322	4 024 704	4 912 180	4 726 881	4 157 814	4 828 918	4 396 130	5 011 021
Crucible cast steel	29 260	34 786	36 328	39 401	39 382	40 430	42 906	56 780
Open-hearth steel	3 000	3 500	7 000	9 050	21 490	25 031	36 126	56 290
All other steel, except Bessemer	7 740	13 714	6 353	12 607	10 306	11 924	8 536	5 464
Bessemer steel ingots	120 108	170 652	191 933	375 517	525 996	560 587	732 226	928 972
Blooms from ore and pig iron	58 000	62 564	61 670	49 243	44 628	47 300	50 045	62 353
Spiegeleisen, included in pig iron	....	....	....	7 832	6 616	8 845	10 674	13 931

In addition to these there are 22 open-hearth steel works, with 33 furnaces, and three are building, with six furnaces, with a total capacity 275 000 tons in ingots. We have, moreover, 35 crucible steel works, and three are building, which will increase our capacity to 90 000 tons a year, besides some miscellaneous steel works, reported as 40 in number.

I will not weary you further with figures, and show our production in anthracite coal, in bituminous coal, in lead, zinc, copper, gold, and silver; although we have, since 1849 (thirty years), produced $1 493 843 430 in gold, and since 1858 (twenty-one years) produced four hundred and twenty millions in silver, but I may be permitted to refer to a few engineering features which mark our more recent American practice.

Among these is the hydraulic system of mining earthy deposits which contain gold dust, even when so little as one cent to the cubic foot. The water is brought sometimes many miles in open ditches, and delivered at the bottom of the mountain to be washed away, through pipes terminating in a flexible hose. Under the impingement of the stream which issues from the nozzle with a head of 200 to 500 feet, the earth melts away like snow, and the economy of labor produced will be best appreciated by an application of this process which took place last April, on the Central Pacific Railroad, near Alta, where a slide brought down upon the track a mass of earth so great that it was estimated that it would take several weeks to remove it with the pick and shovel. The hydraulic engineers being called upon for help, brought up their pipes and monitors, constructed a flume from a ditch which was fortunately near at hand, and in fourteen hours piped away the whole mass of debris which had been the despair of the railway men.

In the reduction of the silver ores such improvements have been made in machinery as very greatly to reduce the cost of working them. The stamp mill, for instance, an old German invention, has been so modified as to increase tenfold its effectiveness, and make it almost an American invention. Such progress has been made in the smelting as to render us independent of foreign works, and few, if any, of our ores are now sent abroad for reduction.

We have also introduced original methods in the extraction of those ores, and on the Comstock lode, which has produced nearly 200 millions of dollars of the 420 millions of silver thus far obtained in the United

States, shafts have been sunk about 3 000 feet deep, which are among the deepest in the world, in a rock which heats the air and water in the mines from 120 to 132 degrees Fahrenheit, thus making these by many degrees the hottest mines known. These have been worked by a novel system of ventilation, by which dry hot air is supplied to the miners, while they have unlimited access to ice water.

Great progress has also been made in applying quick explosives both to tunnelling and mining works, and the Sutro Tunnel, just completed to a length of 20 170 feet, bears evidence to the energy and enterprise of our miners, who have also succeeded in accomplishing great economical results with some of the largest blasts which have been fired in any country.

The discovery of petroleum, of which we produced 19 741 661 barrels, valued on the spot at $17 076 836, from 11 960 wells last year, has caused a revolution in the art of sinking artesian wells for oil, 3 038 of which were put down in 1879.

Such improvements have been made in the tools, and derricks for working them, that the well-borers now generally sink a hole five inches in diameter one thousand feet deep in twenty-five days, an average of forty feet a day, and at a cost not to exceed, including machinery and derrick, of $4 500, while the old pole tools, which these appliances have replaced, could make a progress of but 4 or 5 feet a day. Some of these wells have tapped reservoirs of natural gas instead of petroleum, and this has been quickly utilized in steam engines or in furnaces, while one town at least, that of Fredonia, in the State of New York, is lighted by natural gas at a very small cost.

Reference may also be made to the purely American invention of what is called driven wells, in which, instead of digging in the ordinary manner, an iron pipe, perforated at the bottom and shod with a steel spindle, is simply driven in the ground, in a few hours, to the water-bearing stratum, and yields, upon the application of a pump, nearly as much water as an ordinary house well.

There are yet great possibilities for our mining engineers in the scientific improvement of the present methods, in devising of new machines to work in the mines, of cheaper methods of mining the ores, of reducing them with a smaller consumption of fuel, and of a more complete extraction of the useful metals and minerals from them.

All other industries are to agriculture as dust in the balance ; for if the earth should cease to yield her fruits everything would stop. Agricultural quantities are so vast in the aggregate that apparently small savings of labor, resulting from improved methods or machinery, amount to sums so large, when applied to the whole aggregate, that we can hardly conceive of them.

We have a vast country, with every good gift, and our people have undertaken its development with wonderful energy and success. Although the most of the improvements heretofore made have not been the work of professional engineers, yet they are engineering works. It is therefore proper at this time to direct the attention of engineers to some of the things which have been done during the last thirty years in improving agriculture, that they may see what a field is here laid open to them.

Let us begin with the plow : That instrument, which having superceded the spade and the hoe, is at the foundation of all wealth ; for without the plow there can scarcely be any successful cultivation of the soil. The progress in civilization of different nations may almost be measured by the character of their plows. Many of the nations of the old world still work with such plows as were in use when our Saviour was born.

Up to the present century little improvement was made in this respect. Cast iron plows were then invented, but for a long time farmers would not use them, believing that they "poisoned the land." Improvements were slowly made until 1850, when the New York State Agricultural Society made a grand trial of plows, and found that there was 46 per cent. difference in the power required to do the same work with different makes of this implement.

At that time the cost of plowing in the United States was estimated at twenty millions of dollars. Hence, if the plow having the least draft had been universally used there would have been a saving of 8 400 000 dollars ; or, what would have been probably the case, the farmers would have plowed 113 000 000 acres without more expenditure of power than it did require to plow eighty millions acres. Great improvements have been made since 1850, and the saving derived from the plows now in use, over those of 1850, has been estimated to amount to 45 millions of dollars

annually. Yet the plow of the future has not been invented. The English have made progress in steam plowing by the system of stationary engines and wire ropes, which drag the instrument back and forth across the field, but with our rich soil and thin cultivation this system affords no economy to us over the plowing by horses. We still need a steam plow, perhaps a locomotive one, which shall cover more acres at less cost, and, if required, plow deeper and more thoroughly than the plows drawn by animals, and which shall not be constantly breaking down. The problem, so far, has not been solved. Here is a field for inventive engineers. They will find in Van Nostrand's Engineering Magazine for April, 1878, a capital account by Mr. D. D. Williamson, of what has thus far been accomplished in this country.

The largest single agricultural interest in the United States is the cultivation of Indian corn. The crop of 1877, the largest yet produced, was estimated at 1 342 558 000 bushels, worth, at 35.8 cents per bushel, $480 643 400. Under the old system a man could plant by hand three or four acres a day; now, with a two-horse check-rower planter, twenty acres can be planted in a day. As the planting season lasts about ten days one man can now plant over 200 acres instead of forty.

In old times corn was cultivated by the plow; then came the cultivator. It is estimated that by the use of this implement, as improved at the present day, a saving of five cents per bushel is made over the old method by cultivation by the plow. The saving for the crop of 1877 would therefore have been 67 millions of dollars. This is all due to the more complete pulverization of the soil.

Again: A man can shell by hand five bushel of corn, by working hard ten hours. Thirty years ago this was the only method in use. Now, two men with a machine driven by steam, can shell 1 500 bushels per day. It would take the entire farming force of the corn growing States, at least 100 days of steady work to shell the corn which they raise, if it were done by hand, and it is estimated that it would cost nearly as much to shell the crop as it now brings to the farmer.

Let us take up the wheat crop. It is estimated that the use of the improved seeder, which sows wheat, clover and phosphates all at once, and harrows at the same time, increases the crop of winter wheat at least one-eighth. This represents a saving of 37 millions of dollars.

But the greatest triumph of agricultural machinery is the self-binder

and reaper. A boy driving a pair of horses will reap and bind 15 or 20 acres per day.

One can see on the line of the Northern Pacific, a field of 7 000 acres, producing 154 000 bushels of wheat, at a cost said not to exceed 25 cents per bushel ; all cut, bound and threshed by this machinery. The aggregate saving of cost over the old fashioned methods by the sickle and flail, is estimated at one-third the value of the wheat crop, or 100 millions dollars annually.

Were it not for such inventions as these, and the cheapening in our modes of transportation, we should not have been enabled to compete with the cheaper labor in the basin of the Danube and the Black Sea, in supplying Europe with our breadstuffs.

The attention of this audience of Civil Engineers, is called to the fact, that the cotton crop of the South is yet sown, cultivated and picked by the old fashioned methods, which have scarcely changed in the last sixty years. Were the same inventive skill applied to this industry which we have seen has been applied to corn and wheat, the saving would be enormons.

Immigration has again set in to our shores. After falling off from 449 483 in 1872, to 149 020 in 1877, it has now sprung up again so that 21 094 immigrants arrived in March, and 35 181 in April of this year, at the port of New York ; and these people, most of them in the prime of life, each estimated upon landing to add $1 000, at least, to our National resources, need to be provided for, set down upon farms, and made useful to the country.

Enough has been said to show that this is a branch of engineering too important to be neglected, If Engineers desire to take a higher rank than they now occupy in this country, they must study out new paths for themselves, and be no longer men of routine, ordered hither and thither by promoters of schemes, and the magnates of Wall street.

Transportation of Meats.

The problem of cheaply supplying our cities with animal food, is an important question which is deservedly attracting attention. It is becoming evident that the Western plains and the adjacent territory are to become, if they have not already become, the cattle raising portions of the United States ; where meat will be produced more cheaply than in other parts of the country. The problem is how to convey the animals

to the point of consumption, from 500 to 1 500 miles distant if marketed here, or 4 500 miles away if exported to Europe.

Thus far two systems of transportation have been introduced. The first consists in shipping the animals alive on the hoof, to be slaughtered at the point of consumption. This is mainly done by railroads, and special cars are used for the purpose. The second system consists in slaughtering and dressing the animals, near the point of production, cooling the meat nearly to freezing point, down to the bone; and [shipping it in refrigerated chambers to the point of consumption.

I much wish that some member of this Society, shall study the relative advantages and economy of these two methods, as well as the appliances that have been used or proposed, and give us a paper upon this subject.

The Engineering Future.

Although during the past few years there has been a depression in the progress and undertaking of new enterprises, and a diminished demand for engineers, I do not believe that we are at the end of the great industrial movement which began with the steam engine. I think rather that we stand on the threshold of greater undertakings, and, perhaps, of inventions, which will mark epochs in civilization, and which, whether made here or in some other country, our engineers should be prompt to take up, to perfect, and to introduce.

There are signs that a new motive power will be invented, which shall be safer, of greater energy and less wasteful than steam. You know that chemists tell us that the theoretical energy of a pound of coal, varies between 8 and 11 millions of feet pounds, while we utilize with our best steam engines but from 3 to 11 per cent. of the theoretical value of the fuel. I think it not impossible, that we shall perfect methods of employing directly the gases, produced from our fuels (instead of using them to generate another gas out of water), and thus obtain better economical results than with steam. I know of several promising attempts in this direction,

And, with a new motive power, perhaps will come the solution of the last transportation problem which remains to be solved. I suppose you will smile, when I say that the atmosphere yet remains to be conquered; but wildly improbable as my remarks may now seem, there may be engineers in this room, who will yet see men, safely sailing through the air.

In making this review, I have gone over rather a wide field, and touched upon topics, which some of you, perhaps, may consider as foreign to our profession.

I have, however, but followed the European practice, and that especially of our early professional teachers, the English, who, mindful of the original distinction between the *civil* and military branch, recognize all makers of Marine, Telegraph, Gas, Mining and Agricultural *engines*, as Civil Engineers.

In this country, we have taken hitherto a somewhat narrower view of the province of the engineer. We think of him mainly as a builder of water works, canals, railways and bridges, and we underrate his importance as a builder and applier of machines.

In point of fact, the most important services which the world has received from our profession, have been rendered by the Mechanical Engineers. The men who have reduced the cost of iron and steel to less than half the prices which obtained half a century ago, who perfected the steam engine, who set it to drawing carriages over the land, and driving great ships through the sea, and who harnessed lightning to convey thought, are the men who have made the present development possible, and enabled us to build the public works of the country.

In Europe, the Civil Engineer is required to be much more than a mere designer and layer out of public works. Not only must he thoroughly understand the application of machinery, and be able to devise new methods, if necessary, but he is expected to be a business man, to act as an originator and promoter of new enterprises, as a director or superintendent of public improvements, and as an organizer of labor.

It is, probably, in consequence of that broader understanding of the field open to them, as well as the better organization of their professional societies, that the Civil Engineers have attained a higher position abroad than they have, as yet, in this country; and have attracted into their ranks the most enterprising and gifted men, who remain permanently in the profession; while with us, engineers, cease to be regarded as such by the public, when they achieve success, and become presidents or superintendents of public enterprises.

In France, the direction of almost all departments of public works, is in the hands of engineers, and two of them are members of the present ministry. In England, so great is the confidence that the public have in engineers, that they are constantly called upon to appear before com-

mittees of Parliament, thus coming into contact with the ablest men in the kingdom, to advise them concerning the merits of various propositions; and no new scheme stands much chance of success unless it is approved by the leading members of the British Institution of Civil Engineers, which includes within its list, not only the names of all the eminent men in the profession, but also those of princes, kings, and an emperor.

And now, I suppose you will expect me to say a few words concerning our own Society. It is fairly prosperous. We have now some 600 members,* and while we have been hitherto gaining at the rate of about 30 a year, we shall probably increase by some 100 members this year.

The continued organization of engineers' clubs and societies in various cities, however, (three of them during the past year), and that of a general society of Mechanical Engineers, suggests that there is a want, which we have failed to supply, and raises the question whether our organization, which we have mainly copied from that of the British Institution, is entirely the best for us.

The vastness of our country, and the great distances over which our engineers are scattered, make it inconvenient for them to attend our meetings in New York, which seldom number more than 20 members; while in England, the leading engineers are nearly all within a few hours ride from London, to which, besides, their duties constantly call them.

I believe our organization may be improved upon. We might have a larger number of meetings each year, away from headquarters in New York. The growth of the Society of Mining Engineers to some 900 members in 10 years, may have been partly due to this feature, which has also been adopted by the new Society of Mechanical Engineers.

We might also devise some method of affiliation with the Local Engineer's Clubs in various cities. Most of you remember, that an effort was made in 1873 and 1874, to organize local branches (Chapters, as they were then called), to the Society in various cities. The proposal was much opposed, by some of our oldest and most respected members, and was finally abandoned, mainly, as I believe, for want of an adequate plan.

If, however, we want to raise the professional standard and position, we need a closer union, and greater concert of action, than now obtain

* The British Institution of Civil Engineers numbered on July 2d, 1879, 3,578 members, and is increasing at the rate of some 150 a year. The average attendance at its meetings is 120.

among engineers in this country. A continuance of the present course of division and dispersion, will be certain to have the contrary effect.

I do not believe there is room in this country for more than one first-rate Society of Civil Engineers. It should, in my judgment, include all the men, eminent or rising, in the several branches of the profession, and so raise the professional standard, as to become an influence in society, and truly useful to the country.

Success will depend upon the adequacy of the plan. Let us, therefore, consider whether one can be devised ; and, always bearing in mind, in the words of Telford : "That talents and respectability are preferable "to numbers, and, that from too easy and promiscuous admissions, un- "avoidable, and not infrequently incurable, inconveniences perplex most "societies ;" let us think, whether some changes in our organization, to be thoroughly examined and discussed before they are adopted, shall not raise still higher the standards of technical education, of working practice, and of professional honor.